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ABSTRACT

The "Preparing Elementary Teachers to Teach Mathematics (PETTM) Project" (1988-1991) was a cooperative university/school effort to improve the teaching of mathematics by elementary teachers with its primary focus on improving the university training of preservice teachers (PSTs) in mathematics. This document, volume VI of the project's 5-volume final report, describes the "School Component" of the project. The "School Component" addresses project goals 3 and 4. The report is divided into eight sections. An introductory section includes the background and rationale for the project and a description of its four components. An overview of the school component and a profile of the elementary school chosen as the site are provided next, and subsequent sections describe interventions undertaken at the school to create a problem-solving atmosphere, teacher resource books and videotapes developed for instruction, immediate and long-term impact of the project on the school, and insights into the inservice process. Publications and presentations related to the school component and a description of related instructional products are provided. (MDH)

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Preparing Elementary Teachers to Teach Mathematics:

A Problem-solving Approach

Final Report

National Science Foundation Grant TEI 8751478

Volume IV: School Component

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PREPARING ELEMENTARY TEACHERS TO TEACH MATHEMATICS: A PROBLEM-SOLVING APPROACH

OVERVIEW OF THE ENTIRE PROJECT

The *Preparing Elementary Teachers to Teach Mathematics Project* (1988-1991) was a cooperative university/school effort to improve the teaching of mathematics by elementary teachers. The primary focus of the project was the improvement of the university training of preservice teachers (PSTs) in mathematics. In the late-1980s, Indiana University had been involved in making plans to institutionalize a new four-year program for elementary education majors in 1989. Two elements of this new program were directly related to the work of the *Preparing Elementary Teachers to Teach Mathematics Project* (*PETTM*). These two elements are:

1. each elementary education major must complete an 18-24 semester credit hour concentration in an approved area (one of those areas being mathematics); and
2. each prospective elementary education major must take part in a three semester sequence of concentrated early field experiences working in a school prior to student teaching.

The goals of the *PETTM* Project included:

1) better preparing all elementary school teachers through a problem-solving focus in newly developed mathematics courses at the university;
2) developing a program of concentration in mathematics consisting of some existing courses and some newly developed courses and experiences to prepare students who wish to make mathematics their field of concentration;
3) developing a close working relationship with the local school district to jointly plan for intensive early field experiences for all prospective teachers;
4) establishing support mechanisms to help practicing teachers in the school district broaden their views of the nature of mathematics and to help them utilize innovative teaching techniques for improving their pupils' mathematical thinking skills and use of problem-

solving strategies. As a result, local teachers should eventually be able to serve as role models in the teaching of mathematics using a problem-solving approach for the prospective teachers who visit their classrooms.

Background and Rationale

A number of national reports published in the mid-1980s called for the improvement of education at all levels. Three reports which attracted national attention were the NCATE Redesign (Gollnick & Kunkel, 1986), the Holmes Group report (1986), and the report of the Carnegie Task Force (1986). Based on the assumption that the quality of education is directly related to quality of teachers, these reports proposed dramatic changes in the practices used in recruiting, preparing, and certifying elementary school teachers. Both the Holmes Group and the Carnegie Task Force reports called for the elimination of undergraduate programs. All of the reports proposed broader and deeper backgrounds in liberal arts. The reports also called for closer ties and working relationships between teacher preparation institutions and school districts.

An elementary education Task Force at Indiana University studied the reports and, while seeing merit in many of their recommendations, declined to join the Holmes group. Although educators at Indiana University certainly agrees with the need for graduate work in education, they also feel that such study is more profitable after some teaching experience has been acquired. Further, the Task Force believed that it is quite possible to train elementary school teachers in a well designed four-year program (cf., Mehlinger, 1986). Thus, in 1989, Indiana University instituted their new four-year elementary education program, a program which incorporated many of the recommendations common to the reports mentioned above. Faculty in Mathematics Education and in Mathematics at Indiana University saw the revision of the teacher education program as a unique opportunity to improve the mathematics preparation of elementary teachers.

Project Description

The *Preparing Elementary Teachers to Teach Mathematics Project* was comprised of four components, all of which were designed to contribute to improving mathematics instruction in elementary schools: the *Content Component*, the *Methods Component*, the *School Component*,

and the *Research and Evaluation Component.*

The *Content Component* involved revision of the university mathematics courses required of PSTs in a fashion that could be exported to other teacher training institutions. Under the new Elementary Education program, prospective elementary teachers would take two mathematics courses: a finite mathematics course (M118—already required of freshmen intending many majors) , and a newly designed mathematics course specifically for education majors (T104). Under project auspices, the former course was restructured and the latter designed completely from scratch, so that problem solving is now a central focus in both. In other words, efforts are now being made to teach university-level mathematics with the same problem-solving approach that the Project would like to see teachers use when they work with children.

The *Methods Component* of the Project had three major goals: 1) to develop well-structured field experiences for both the existing mathematics methods course and a proposed new problem-solving methods course, 2) to develop and institutionalize the new problem-solving methods course (to be required, along with additional mathematics courses, of those students who would elect mathematics as their area of concentration), and 3) to develop a computerized problem-solving data bank to be available for use not only by students enrolled in methods classes and field experiences, but also by prospective teachers in other courses and local teachers in the schools.

An important part of the training of PSTs is experience with classroom teachers and their students. The purpose of the *School Component* of the Project was for Indiana University faculty to work together with faculty from a local elementary school (Dyer/Highland Park) to provide the best possible environment for early field experiences in mathematics for IU students. A full-time resource teacher worked closely with the Dyer/Highland Park School faculty for three years, helping them develop the confidence and expertise necessary to teach mathematics using a problem-solving approach. Five teachers from the school worked for two summers writing books of problem-solving materials that they, and their colleagues, could use with their students. The university-school partnership was a very successful part of the project.

The main purpose of the *Research and Evaluation Component* was to determine the

effectiveness of each of the other components of the project. A long range goal of the entire project was to provide an improved model for training elementary teachers. By finding out which innovations were effective, the project was able to provide a tested plan for training elementary teachers to teach mathematics.

Conclusion

The *Preparing Elementary Teachers to Teach Mathematics Project* was multifaceted, aiming to improve the teaching of mathematics in the elementary schools by encouraging teachers to use a problem-solving approach. Although the major focus of the Project was the design and implementation of a new program of studies for prospective elementary teachers at Indiana University, an essential element in this endeavor was the establishment of Dyer/Highland Park Elementary School as a site for all Project-related field experiences, and the provision of frequent and ongoing inservice work for the Dyer/Highland Park faculty so that school could serve as a model site for the teaching of mathematics with a problem-solving approach.

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PREPARING ELEMENTARY TEACHERS TO TEACH MATHEMATICS: A PROBLEM-SOLVING APPROACH

Overview of the School Component

The School Component of the Preparing Elementary Teachers to Teach Mathematics (PETTM) project was a collaborative arrangement between project staff and the staff of Highland Park Elementary School in Bloomington. The rationale for the School Component was that preservice teachers needed a site where they could take part in teaching mathematics from a problem-solving perspective. In addition, PETTM staff needed opportunities to explore innovative teaching strategies with children. At the time that the proposal for the PETTM project was being developed, the faculty at Highland Park agreed to work together with PETTM staff to make Highland Park that site. Note that, for consistency, the name Highland Park will be used in this report even though it was not the name of the site at the time the project began. At the time, and during the first two years of the project, the school site was called Dyer Elementary. At the end of the second year of the project, the Dyer students and faculty moved to a new facility called Highland Park. Because the school is currently located in the Highland Park building, it is referred to as Highland Park throughout this report.

Of the four major goals of the PETTM project, the last two involved the School Component. Those goals were:

> The PETTM project will develop a close working relationship with the local school district to jointly plan for intensive early-field experiences for all prospective teachers.
>
> The PETTM project will establish support mechanisms to help practicing teachers in the school district broaden their view of the nature of mathematics and to help them utilize innovative teaching techniques for improving their pupils mathematical thinking skills and use of problem-solving strategies. As a result, local teachers should eventually be able to serve as a role model in the teaching of mathematics using a problems solving approach for the perspective teachers who visit their classrooms.

In other words, our goals were to (1) gain the trust of the teachers in a local school, in this case Highland Park/Dyer, (2) help the teachers in that school to broaden their view of mathematics and the teaching of mathematics to include problem solving and mathematical thinking, and (3) to help the teachers integrate mathematical thinking-skills activities and problem-solving activities into the regular mathematics curriculum.

Profile of Highland Park Elementary School

With a population of approximately 500 pupils in grades K-6, Highland Park Elementary is the second largest elementary school in the Monroe County Community School Corporation (MCCSC). Over the three years of the project, the number of classrooms within the school has fluctuated, but in general the school has contained 22 classrooms, one kindergarten classroom (for two half-day classes), three classrooms at each of the primary grades (1-3), two classrooms at each of the intermediate grades (4-6), and six special education classrooms.

The students at Highland Park represent a socioeconomic mix. A small number are children of professionals or of university faculty although the majority come from families with much lower income levels. Half of the Highland Park children qualify for free or reduced-price lunches, and approximately 80 percent of the children are labeled using MCCSC criteria as "at-risk" students.

Highland Park faculty were originally asked to participate in the PETTM project because they had been involved in field experiences for preservice teachers (PSTs) and because they felt they could profit from a program designed to broaden their views of mathematics and their notions of how problem solving can be integrated into the elementary mathematics curriculum. Many teachers who were at Highland Park at the start of the project were career professionals with ten or more years of experience. This faculty makeup was typical of MCCSC at the time because very few new teachers were hired in the mid to late 1980s. During the second and third year of the project several additional beginning teachers joined the staff. The Highland Park faculty are dedicated educators, but because of the large percentage of at-risk and hard to control students, teacher burnout has been high and teacher attrition has been considerable. Only 60 percent of the teachers who began the project in the 1988-1989 school year, returned to Highland Park for the 1991-1992 school year (see Appendix A).

One of the first things that the mathematics resource teacher and other PETTM staff did when the project began was to sit in the classes at Highland Park (Dyer at that time) to get a better feel for the teaching that went on there. As was the case with all observations of Highland Park teachers, the objective was to understand the environment rather than to pass judgment on it. Based on those initial observations and discussions with faculty, several characteristics of the school emerged.

First of all, there was typical enthusiasm on the part of many students at Highland Park although there were also a number of students who were obviously turned off by school. The teachers were friendly but there was an underlying current of mild hopelessness with many students. At times the teachers seemed tired, strained, and unable to make the school atmosphere as positive as they would like. Although the principal had said the faculty were enthusiastic about

being part of the PETTM project, several teachers noted that the enthusiasm was far from universal. Teachers were often somewhat apprehensive about having PETTM staff in their classes but it was hard to say whether this was a reaction to "university personnel" or whether it was a reaction that was triggered by any outside person whose role was not clearly defined.

The role of the students in mathematics classes was generally quite passive. One third grade teacher was observed using questioning during a science class and a sixth grade teacher was observed going through process problems with her students. In general, however, most mathematics classes were quite traditional. The teacher collected or graded homework, a brief explanation of new material was provided, and students worked at their desks on problems from the textbook. When students interacted with other students, discussion usually focused on what the correct answers were rather than how those answers were arrived at.

Manipulative materials were used on a limited basis. The primary classrooms sometimes used play money or clock faces. Each teacher had been supplied by the school district with a selection of other manipulatives. Unfortunately, there were only enough of these manipulatives for one or two students. They were used by some teachers for demonstrations while other teachers did not bother to use them at all.

In brief, at the time the project began, Highland Park (Dyer) had a fairly traditional mathematics program. The faculty were generally experienced teachers who used direct instruction methods with, by local standards, a fairly low achieving and hard to manage student population.

Interventions

To reiterate, the three goals for the school component were (1) to gain the trust of the teachers at Highland Park, (2) to help the teachers broaden their view of mathematics and the teaching of mathematics to include problem solving and mathematical thinking, and (3) to help the teachers integrate mathematical thinking skills activities and problem-solving activities into the regular mathematics curriculum. These goals are closely tied to one another and were accomplished through common interventions.

Gaining Acceptance

A very important step in any educational intervention is to gain the acceptance and trust of the individuals for whom the intervention is intended. Until rapport was established and Highland Park teachers, particularly veteran teachers, felt comfortable enough to make mistakes in front of PETTM project staff, the other goals could not be accomplished. Both the aquistion of trust, and the gaining of acceptance take time. Time was needed both to allow teachers to realize the respect that PETTM staff, including the resource teacher, held for them. Time was also needed to allow the faculty to become acquainted with the resource teacher as a professional and as a person. To this end, the resource teacher participated in school and faculty functions, such as attending the

weekly faculty breakfasts, participating in faculty meetings, and working at the school carnival. The resource teacher time also spent with faculty on an individual basis. She wandered the halls, stopping by classrooms before and after school to talk with teachers. For the first two years, her office was set up in high-traffic areas, the main office and the faculty lounge, which allowed for daily, informal interaction. By the end of the first semester of the project, the faculty began to feel comfortable sharing their thoughts and ideas with the resource teacher.

Providing Information

The second goal of the school component was to help the Highland Park faculty broaden their views of mathematics and the teaching of mathematics to include problem solving and mathematical thinking. For this goal to be met, the teachers needed to be exposed to this different view of mathematics and to be shown how it could be applied to the classroom. Information was disseminated through resource materials, workshops, and individual interventions.

Mathematics laboratory. Even though space was at a premium at Highland Park, space for a mathematics laboratory was provided in the school. The PETTM project provided resource materials and manipulatives specifically for the use of the Highland Park faculty. The lab had class sets of manipulatives which the teachers could check out for use with their classes as well as written resource materials which helped them to plan lessons using both manipulatives and a problem-solving approach to teaching. A complete inventory of the materials provided for the mathematics laboratory by the PETTM project can be found in Appendix B.

Workshops. A second way of providing new insights into the teaching of mathematics was through a series of workshops. The Mathematics Education Development Center provided a one day "kick-off" workshop just before school started in each of the three project years. These workshops introduced the Highland Park faculty to aspects of teaching problem solving and to teaching mathematics with a problem-solving approach as well as serving to further acquaint the PETTM Staff to the faculty. During the first two years, the kick-off workshops were supplemented by after school workshops funded by the Indiana Department of Education and the Indiana Commission for Higher Education. Briefly, the workshops introduced the Highland Park and other area teachers to important contemporary topics in mathematics education. Each series was composed of six workshops which featured mathematics educators from around the country who had an expertise both in their topic area and in applying that topic to the elementary classroom. Topics covered included teaching problem solving, teaching estimation, using calculators, using manipulatives, using cooperative learning, working with special needs students, and integrating reading and mathematics. (See Kloosterman et al., 1989, and Kroll et al., 1990, for complete descriptions of these workshops).

Individual interventions. The project staff provided support as the Highland Park teachers attempted to integrate the new ideas gained from the materials and the workshops into their

mathematics curriculum in the form of model teaching and consultations. Approximately every three weeks, the resource teacher visited each classroom and taught a lesson which modeled such things as teaching through questioning, strategies for teaching problem solving, teaching particular topics, or using manipulatives. At the beginning of the project, the resource teacher initiated the visits but as the project progressed, teachers took more and more initiative in scheduling the visits. The topic of the lesson was often requested by the classroom teacher, with the resource teacher balancing traditional topics with nontraditional topics such as geometry, probability, mental mathematics, number sense, place value, and problem solving. Regardless of the topic, the lesson was taught through critical questioning with an aim of helping students to deepen their understanding of the concepts and allowing them to verbalize their conceptions.

The resource teacher also served as a consultant to the teachers, suggesting materials to extend both model teaching lessons and workshop ideas, and helping interested teachers to design units or find materials to supplement more traditional materials in their textbooks.

Summer resource books. Although a variety of supplemental resource materials are available for teaching mathematics from a problem-solving orientation, to be most effective those materials need to be adapted to the specific needs and interests of teachers and students in a school. In the spring of 1989, six teachers at Highland Park were asked to join the resource teacher and other PETTM staff to develop resource books that could be used in teaching mathematics. The teachers selected represented each grade level (1-6) and had all been actively involved in the PETTM project.

Initial development of the resource books took place during a four-week period in June and July of 1989. The teachers were paid through PETTM funds to work 20 hours each week at the Mathematics Education Development Center at Indiana University although most put in many additional hours at home. Time was spent searching available resources for ideas that would be useful at Highland Park. The teachers usually worked in pairs although there were several group meetings each week. At the end of the session, a resource notebook had been compiled for each grade level. Although the books contained numerous ideas, they were each organized differently and were difficult to understand by individuals who had not been involved in their preparation.

During the 1989-90 school year, the teachers who had put together the resource notebooks tried out the ideas in their classrooms. As each activity was completed, notes were made about its effectiveness and needed changes if the activity was to be used again. In the summer of 1990, five of the six teachers returned for another four-week session to revise the books. The focus of the revisions was to make the books usable by other teachers who had little special training in mathematics. Because of the different interests of the teachers, it was decided that each book would have a topical rather than grade level focus. Four books were compiled, one on "problems of the day," one on logical thinking problems, one on project problems, and one on process

problems. When the books were completed, the Highland Park teachers who were involved in their development provided inservice on using the books to other teachers in the area. More detail on the books can be found in the products section of this report.

Creating a Problem-solving Atmosphere

To accomplish the goals of the PETTM project, it was necessary to supplement work with individual teachers with projects designed to create a problem-solving atmosphere for the school as a whole. Several schoolwide interventions took place. These included challenge problems, parent newsletters, and a school-wide mathematics fair.

Challenge problems. Each month, a primary-level and an intermediate-level "challenge problem" were displayed on a bulletin board outside the school office during much of time the project took place. All students were encouraged to solve the problems, and to turn in both their solution and an explanation of their work to the resource teacher. The names of the students with correct solutions were displayed beside the problem. Congratulatory letters were sent to the parents of these students and certificates were awarded to students at the end of the year.

Math Message. In order to inform the parents of the project, a newsletter titled the *Math Message*, was sent home several times a year. It's purpose was to inform the parents of the project, and to suggest ways that they could help their students become better at doing mathematics.

Math fair. To give the parents a hands-on example of the mathematics their children were learning, and to further challenge the students, a mathematics fair took place each spring. Students in each classroom were presented with a problem, which they solved in small groups with the aid of an Indiana University student who was participating in Early Field Experience. Problems/projects for the fair included designing a playground using a specific budget, finding the most common letter in the alphabet, and determining the most popular lunch served by the cafeteria. In addition to solving the problems, groups of students prepared hands-on explanations for their parents. The results were displayed during an evening fair in which parents both came to see their children's ingenuity as well as to attempt to solve similar problems.

Joint Activities

As noted, a major goal of the PETTM project was developing a partnership arrangement with the faculty of Highland Park. In any productive partnership, all parties provide resources that result in benefits for all involved. The partnership between the Mathematics Education Development Center and Highland Park Elementary School resulted in a number of outcomes that were beneficial for both.

M201. A major reason for instituting the School Component of the PETTM project was to provide a site for the early field experience program for preservice elementary school teachers (PSTs) at Indiana University. This field experience, called M201 in the University Catalog,

includes teaching in both mathematics and science. The IU students enrolled in this course taught mathematics to small groups of elementary students four times each semester. Besides being an invaluable learning experience for the PSTs, this experience provided hands-on learning experiences for the elementary students in math areas, either reinforcing traditional material or presenting material which might not have been covered in the students' regular mathematics classes. This experience also challenged Highland Park faculty members to come up with new ways to teach mathematics so those ways could be discussed with PSTs.

Tutoring program. As is discussed in the methods component of this final report, PETTM staff set up an experimental tutoring program at Highland Park. This program influenced both the faculty and the elementary students. It's benefit to the elementary students is obvious. Like the M201 early field experience, the tutoring program allowed the Highland Park faculty to become teachers of future teachers and to think of new ways of helping slower learning students. The program also helped to build a strong sense of partnership between the university and the elementary school.

Internships for graduate students. Another endeavor which proved beneficial to both the university and the elementary school was the placement of mathematics education graduate students in the school for internships. Many doctoral students in mathematics education begin the program with experiences in high school or college teaching but with little or no experience at the elementary level. To broaden the experience base of these individuals, several were placed in classrooms at Highland Park. The Highland Park faculty became mentors to the graduate students, giving the students the opportunity to try ideas and to gain confidence in their own abilities as teachers. The graduate students gained invaluable experience as well as new respect for the art of teaching elementary students.

Site for learning research techniques. Finally, Highland Park provided Indiana University graduate students with a site where they could gain experience in doing research. Graduate students observed classroom teachers, gaining more elementary experience as well as learning observation and interviewing techniques. Elementary students were interviewed as part of the Research and Evaluation Component of the Project. Problem-solving tests and other quantitative measures were also developed for use at Highland Park. More detail on the types of research that went on at Highland Park can be found in the Research and Evaluation section of the final report.

Products

As part of the goals of establishing a cooperative relationship with Highland Park Elementary and helping the faculty to integrate mathematical thinking skills into their regular mathematics curriculum, two "hard products" were produced. As noted in the section on

interventions, teacher resource books were developed. In addition, several videotapes of "model" mathematics teaching were produced.

Teacher Resource Books

The teachers who worked in the summer had the task of producing resource books to assist them in teaching problem solving on a day-to-day- basis. The end result of two years of work was four problem-solving books. (Photocopies of these books can be obtained, at cost, by contacting any *Kinkos* copy center in the nation and telling them that the books are available from the Bloomington, Indiana *Kinkos*, 113 N. Dunn St., 812 339-3773. Kinkos is a nation-wide photocopy chain usually listed in the yellow pages of the phone book under "printers.")

A Problem a Day for Primary People is a book of translation and process problems which can supplement any primary level elementary text book. The book consists of three sections: 150 problems for first grade, 150 problems for second, and 150 problems for third grade. Besides the problems, the book also discusses specific questions often asked by teachers such as "Why should I teach problem solving?" "What is my role as a teacher?" and "How do I evaluate problem solving?" Each section contains sample teaching questions, lessons wrap-ups, and problem variations.

A Logical Mystery Tour is a book of logic problems for students in grades 1 through 6. The book presents three types of logic problems, "Who am I" (attribution) problems, "Line-Up" (sequencing) problems, and "Matrix" problems. The problems within each section are organized form the least to the most difficult, and include teachers' pages with ideas for facilitating classroom discussion and guiding students through the problems. The introduction to this book also addresses common concerns of teachers and suggestions for evaluating student learning.

Projects for Real-World Problem Solvers is a collection of mathematical project problems which can supplement a regular mathematics program in grades 1 through 6. Each of the 14 projects is a "real-life" problem which is open-ended to allow the students to decide on the direction they should take and the strategies that should be used to solve the problem. The book contains introductory materials on teaching actions, grouping students, and helping students who are having difficulty.

A Packet of Problems to Ponder is a book of 66 process problems for the intermediate grades. The first fifteen problems are presented with a teacher page which gives suggestions for possible strategies, discussions questions, hints, and variations of a problem. To aid in instruction, much of the book is organized by the most common strategy used to solve the problems. The final problems are provided for additional work and are organized by difficulty rather than solution strategy.

Video Tapes

Video tapes of problem solving lessons or lessons taught with a problem-solving approach

were made for use with pre-service teachers. Each tape contains 15 to 30 minutes of classroom instruction. Most methods course instructors will find that, when combined with discussion, a tape is about the right length for a 50 to 60 minute class period. Following is a list of the tapes that have been made.

Title: *Teaching Fractions Using Cuisinaire Rods*
Code #: E1
Topic: Teaching Fractions with Cuisenaire Rods
Grade: 6
Teacher: Jacqueline Gorman

Title: *Teaching Problem Solving: The Making Flowers and Making Sandwiches Problems*
Code #: E2
Topic: Process Problems
Grade: 1 and 2
Teacher: Bette Calkins and Lisa Bays

Title: *Teaching Fractions Using Pattern Blocks.*
Code #: E3
Topic: Teaching Fractions with Manipulatives
Grade: 3
Teacher: Barb Burnett

Title: *Problem Solving Using Number Tiles*
Code #: E4
Topic: Problem Solving with Manipulatives
Grade: 4
Teacher: Margie Simmerman

Title: *Using Patterns to Find the Number of Squares*
Code #: E5
Topic: Process Problems
Grade: 4
Teacher: Jacqueline Gorman

Title: *A Geometric Investigation: How Many Lines are Determined by "X" Points*
Code #: E6
Topic: Teaching Geometry Using a Problem-Solving Approach
Grade: 6
Teacher: Jacqueline Gorman

Title: *Preparing Elementary Teachers to Teach Mathematics: A Problem-Solving Approach*
Code #: P1
Topic: Overview of PETTM project
Grade: Teacher Education
Teacher: Varies

Title: *Building Toothpick Bridges*
Code #: P2
Topic: Project Problems

Grade 6
Teacher: Tammy Miller

Title: *The Dyer Mathematics Fair*
Code #: P3
Topic: Project Problems
Grade: Varies
Teacher: Various PSTs

Title: *Teaching Problem Solving: The Tables Problem*
Topic: Process Problems
Grade: 3
Teacher: Jacqueline Gorman

Title: *Teaching Problem Solving: The Squirrel in the Tree Problem*
Topic: Process Problems
Grade: 3
Teacher: Jacqueline Gorman

Title: *Teaching Fractions Using Fraction Strips*
Topic: Teaching Fractions with Manipulatives
Grade: 5
Teacher: Mamie Merrifield

Videotapes of additional problem-solving oriented instruction have been made and are currently being edited. The extent to which these tapes will become available depends on the resources available for additional editing.

Impact of the Project on Highland Park Elementary

The project had impact both on the total school and on individual teachers at Highland Park. This section discusses the impact on both of these groups based on observations made at the school, and comments made by teachers both informally and on year-end questionnaires and the end-of-project exit interviews. (See the Research and Evaluation section of the report or the summary of the exit interviews in Appendix C for more detail on the data sources on which conclusions are based.)

Impact on School Climate

Problem solving. At Highland Park, problem solving in the form of process problems, puzzle problems, and logic problems now occurs on a regular basis. In many classrooms, there is a "problem of the day" on the chalkboard. All students work on the problem and discuss it either with a small group or the whole class at some time during the day. In other classes, non-routine problems are presented several times a week. In still other classrooms, process problems are integrated into mathematics content units to create motivation and show application of the mathematical topic being investigated.

Questioning techniques. Besides incorporating non-routine problems into the curriculum, most teachers have changed their teaching behavior during mathematics classes. They use a more problem solving approach to the teaching of mathematics, seeing their role as learning facilitators rather than suppliers of factual information. During interviews with Highland Park faculty at the close of the PETTM project, most claimed that their mathematics classes involved much more discussion than they had in the past, with students doing a greater part of the explaining and discussing with each other to support their thinking. The teachers no longer felt that they had to be the "answer books."

Use of materials. The use of manipulatives has increased at Highland Park, although they are more commonly found in some classes than in others. In some cases, manipulatives are used only on a limited basis because the teachers feel their students function best within the tightly controlled structure provided by textbook assignments. Most teachers, however, use manipulatives on a regular basis. In some cases, manipulatives are used at learning centers and in others, they provide background for group as well as whole class discussion.

Attitude of faculty. The attitude of the faculty changed in several respects over the duration of the project. Their attitude toward the university personnel changed from suspicious to accepting. This was true for the school resource teacher and for all MEDC personnel. A partnership based on trust and mutual respect has been established.

Faculty attitude toward mathematics has also changed. Math in now seen as a creative subject where the process is important and where routine skills can be learned through application and problem-solving activities.

Most importantly, faculty at Highland Park have gained substantial confidence in their ability to teach mathematics to low achieving children. During the project, they were treated as professionals. They now freely question both university personnel and textbook writers. They trust their judgments to what is best for their students.

Student role during classes. The students have become more active learners. They have become much more willing to answer questions, to try different or novel ways of solving a problem, to make conjectures and to defend their reasoning. These behaviors were witnessed even during video tapings when one would expect students to be hesitant to speak out when unsure of themselves. Students are beginning to look for patterns on their own, are more independent during problem solving, and even feel free to question their teacher's solutions.

Impact on Individual Teachers

In the addendum to the original proposal for the PETTM project, it was acknowledged that while "some of the teachers will not become 'outstanding models' in teaching mathematics," we were confident that "most if not all teachers will incrementally approach the state of being a model teacher." We feel that these predictions have been fulfilled. Most Highland Park teachers have

become, if not "outstanding models," at least very good mathematics teachers. And although all teachers have been at least somewhat changed, most teachers have expanded their view of what mathematics is. The prevalent pre-project view of mathematics was that it involved computation almost exclusively. This view has been expanded to include an emphasis on understanding concepts behind the computation, the development of a sense of what an answer should be, and an emphasis on process as well as accuracy. Topics included in "definitions" of mathematics now include geometry, patterning, mental mathematics, estimation, and problem solving. The teachers now speak of the necessity of integrating mathematics into all aspects of the curriculum, emphasizing the usefulness of mathematics, and applying mathematics to everyday life. Most teachers have broadened their teaching strategies to include student dialog, use of manipulatives and they now tend to use the mathematics book as a guide rather than a Bible.

In brief, teachers have been affected to various degrees. For some teachers, the PETTM project has had a major affect, and for others the project has had at least modest influence. Some of the faculty at Highland Park, especially those who started during the last year of the project, were beginning teachers who had just completed the undergraduate program at Indiana. For these teachers, PETTM reinforced ideas that they had gained in their preservice courses. A handful of teachers, for various reasons, were only slightly affected by the project. More complete information about individual teachers can be found in the teachers' exit interviews (Appendix C).

Major effect. The five teachers who worked with PETTM staff for the two summer writing sessions had dramatic changes in both their perceptions of what mathematics is and how mathematics should be taught. They have all become teachers of teachers, working as mathematics resource teachers by inservicing other teachers. These individuals have given presentations at professional meetings and have coached teachers at other schools in the area. These five teachers have fairly sophisticated views of mathematics, seeing it as a way of thinking or a process. These teachers feel safe using the mathematics text as a guide, but do not necessarily feel tied to its sequence or to the extensive use of drill in the exercises. They have enough confidence in themselves as math educators to trust in their judgments about what is best for their students. These teachers strongly emphasize the necessity for student discussion during mathematics, believing it is important for students to be able to explain concepts, to defend their solutions, and to make conjectures. These teachers use a variety of teaching techniques, but emphasis is placed on the understanding of the concepts. We believe that this group of teachers has a firm enough grasp on the philosophy behind teaching mathematics with a problem-solving approach that they will continue to grow as mathematics educators.

Substantial but not major effect. Another group of approximately five teachers were substantially affected by the project although not as strongly as the previous group. These teachers did not have the opportunity during the summers to examine materials, and evaluate what was

important to them, but they were basically teachers who were interested in making a change in the way they taught mathematics. They were teachers who took advantage of both the workshops and the resource teacher from the beginning of their involvement with the project.

For the most part, these teachers do not have the knowledge of the resources that the prior group has, and have not given teacher inservice, but they view mathematics and the teaching of mathematics more broadly than they did at the start of the project. They minimize their use of drill and practice, emphasizing strategies and the process involved in arriving at answers. Student discussion is valued during mathematics class, some manipulatives are used during class and problem solving is emphasized. There is little doubt that this group of teachers do an excellent job of teaching mathematics and, along with most teachers at Highland Park, will continue to grow as mathematics education professionals.

Reinforced ideas. For three individuals, the last year of the PETTM project was their first year in the classroom. All three of these individuals received their undergraduate training at Indiana University and had been introduced to the problem-solving approach of teaching mathematics through their mathematics methods classes. By the third year of the project, experienced teachers at Highland Park were involved in training other teachers to teach mathematics and thus acted as mentors for the new teachers.

During the exit interviews, it became apparent that what the three beginning teachers had learned in their undergraduate methods class was reinforced during their first year of teaching, both by the project staff and by their colleagues. As would be expected of first-year teachers, much of their energy at the beginning of the year was spent on classroom discipline and "surviving." As the year progressed, however, and they developed more skills and confidence, these teachers branched out mathematically, involving more problem solving and use of manipulatives in their classrooms.

Modest effect. While all teachers were affected by the project, we feel that there was a small group of four teachers who were affected to a lesser extent than the rest of faculty. This group can be subdivided into two pairs. The first of these pairs were very cooperative with the project staff and seemed to want to change. They had the best attendance of all Highland Park teachers at the state sponsored after-school workshops and seemed very open to the ideas presented. They now teach children problem-solving strategies and include significant amounts of work on place value and number sense. These individuals, however did not integrate many of the workshop ideas into their teaching and probably changed less than most other PETTM participants. This may have been because they had very difficult groups of students to work with or it may have been that they needed more support than they received. One of the regrets of the PETTM staff is that neither of these teachers were invited to join the summer writing sessions. They were enthusiastic and their ideas and perspectives were much different than those teachers who

participated.

The second pair of modestly affected teachers seemed fairly resistant to the change during the first half of the project. They seemed satisfied with the way that they were teaching mathematics, and although they were not hostile, they made no attempt to come to workshops and did not seem interested in integrating techniques which they observed from project staff. However, during the exit interviews, both of these teachers stated that they had changed. They both felt that they emphasize thinking processes and problem solving during mathematics classes more than they did prior to the project.

Long-term Impact of the Project

As with any inservice-oriented project in education, there is no guarantee that changes in place at the end of the project will continue indefinitely. Some changes will continue to evolve and some changes will revert to previous conditions. We do not view this as failure but as part of the natural order of life. The following discusses our assessment of the potential for long term impact of the project on the Highland Park faculty, Highland Park as a school, and the Monroe County Community School Corporation as a whole.

Faculty Change

There is no question but that the PETTM project had a positive impact on all Highland Park teachers. The question that does remain is the strength of this impact. Teachers who were strongly effected will probably continue to take interest in teaching mathematics well and will continue to grow professionally. For those teachers on who the project had only modest impact, it is possible that enthusiasm generated by the project will result in substantial growth in future years. A more likely scenario, however, is that these individuals will continue to be concerned about teaching mathematics well, but rather than being leaders in mathematics teaching, will progress at a rate typical of teachers who have not had the opportunity to participate in a project of this type.

Site Change

It is difficult to predict how long Highland Park Elementary School will continue to be a site for excellence in mathematics teaching. Almost all educational innovations eventually fade in impact and we fear this could eventually be the case at Highland Park. On the optimistic side, the teachers who have been affected most by the PETTM project continue to teach at Highland Park and serve as models and mentors for new teachers at the school. When the Highland Park building was constructed two years ago, a special mathematics and science laboratory was included. The resource books and laboratory materials remain in that laboratory and, for the forseable future, PSTs will be engaged in early mathematics field experiences at Highland Park. Thus, although mathematics teaching at Highland Park will continue to evolve, we are optimistic that there will be

a long-term commitment to teaching from a problem-solving orientation at Highland Park.

Corporation Change

Two years of State sponsored and MEDC produced inservice workshops for MCCSC elementary teachers has helped rekindle an interest in many local schools to emphasize understanding and problem solving in mathematics classes. The local district administration has supported this and a majority of the new teachers hired have completed their preservice training at Indiana University. Local administrators have used the strongest Highland Park teachers as "lead teachers" to coaching a small numbers of teachers from other schools. The administration has also funded teachers to attend workshops and hired mathematics consulants. As long as the administration continues, we are optimistic that positive change will continue at the local and regional level.

Insights About the Inservice Process

The interaction with the Dyer/Highland Park faculty and students has enriched us with new knowledge and insights. We have a better grasp on how to implement change, a greater understanding of factors which limit change, and a wealth of experiences which have helped us realize the reality of teaching in today's society.

Necessary Ingredients for Implementing Change

For an outside force to attempt to implement change in any setting is an arrogant business. The outside force assumes that what is in place is not "good enough" and that it has the answers. In an elementary school, this arrogance is particularly unwelcome because of the recent poor publicity which has surrounded education, especially elementary education. If the "outside force" source is a university, there also exits a credibility gap between practicing teachers and theorists. For the outside force to implement change, it must counteract this arrogant image and show that it has a relevant message to offer.

Respect for teachers. The single most important ingredient for positive change to occur is a conveyance of respect for teachers and their present knowledge and skills. This cannot be a patronizing or false respect. Partnership must be based on each party knowing their own strengths and weaknesses as well as knowing and valuing the strengths and weaknesses of the other members. Teachers must realize that we while we have a specialized knowledge, their experience and knowledge are needed to make it a product which is usable in the classroom. Treating teachers as professionals and acknowledging to them that their knowledge is valued strengthens their self-esteem and makes them stronger partners.

Relevant message. For change to be implemented, the message sold to teachers must be of value to them. Their lives are too hectic, their time is too precious for the trivial or the impractical. The message must be something for which they can see value and, if possible, be

something of which they can have a sense of ownership.

Time. The clearest message that we received from the teachers is that change takes time. At the end of the first year of the project, one of the most active teachers told us that she had just realized that math could be taught differently, now she was ready to learn how to teach it differently. It takes time to take on a philosophy. It takes time to learn new skills. It takes time to change old habits. Our three years of involvement has greatly changed the teachers who were waiting for a change. We need another two years to make substantial changes in the rest of the faculty.

Besides length of time, the intensity of time is important. The teachers who made the greatest changes were those who spent two summers examining a huge collection of math resource books. The same collection was available to them throughout the school year, but they did not have the time, nor the motivation for in-depth examination. During the summer, they were given a definite task, a purpose for looking through those books. Teachers need purposeful time which is set aside from their normal day if they are to think about and undertake new ways of teaching.

Mentor. Another necessary ingredient for change is support. As Mamie Merrifield told us, the two things that we did "most right" were to give them time and support. Teachers needed to see techniques such as questioning styles or class discussion instead of just hear about them. They needed someone there to prod them into trying something new, to encourage them when they tried something which didn't work well, and to see someone else fail with their own students. They needed someone who could quickly direct them towards a resource or who could sit down to help them plan a unit. Interestingly enough, just the fact that someone they trusted was available, gave the teachers support without that mentor actually intervening. It was the security rather than the actual intervention that seemed to be needed. Having a mentor was the single biggest ingredient that teachers gave in the change formula.

Materials/ideas. An obvious ingredient for change is the access to new ideas. Teachers will often be unsatisfied with what they are doing but have no idea of how it can be changed. They need something to wet their creative juices, to spark their imaginations. They should not have to reinvent the wheel, especially once that wheel has been thoroughly perfected by someone else. They do need to be introduced to that wheel though, and to be allowed to play with it and to adjust it to fit their own teaching style, classroom needs and personality. Teachers need access to various ideas. These ideas can be presented in workshops or courses, but there should be resource books and materials which are classroom ready for follow up. After teachers have had a chance to become familiar with an idea or philosophy and have had time to experiment with written materials, they may be ready to start creating their own materials.

Ingredients which Limit Change

Degree of interest of teachers. If teachers aren't interested, you can't force change. Most teachers are interested in being good teachers. If you can show them something which works and fits with their values and goals, they will give you the as much energy as their work load allows. But if they aren't interested, they can't be forced. Treat teachers as professionals and allow them to join you when they are ready. Keep the invitation open. If they see others are involved and successful and they are not feeling excluded, they will come around.

Limitations imposed by type of student. Not all things work with all students. Although there are individuals who would disagree, we feel that there are classroom situations where manipulatives and small group activities are impractical without spending major amounts of time socializing the students. The students in some classes at Highland Park were not mature enough or socialized enough to have the necessary skills for working with materials or peers. Some teachers were willing to sacrifice time that could be used for teaching content to work on interpersonal skills. Others were not.

Limitations imposed by administrative support. Administrative support for change is an important influence on the effectiveness of programs for change. Some teachers are always looking for ways to improve and will change unless administrators actively discourage such change. Other teachers often need a "push" to get started and administrators can be very helpful in this regard. In general, the greater the administrative support, the more teachers are likely to change. An administrator who says teachers need to teach mathematics in new and better ways is advantageous. An administrator who participates in mathematics workshops, finds money for manipulatives, and encourages teachers to work together for change is even better.

Limitations imposed by amount of money. As with all of education, money is a factor limiting innovation. In most professions, funds are set aside for new technology and materials and for training individuals on the use of materials. For elementary mathematics teaching to significantly improve, teachers must have access to manipulative materials and be paid to learn to use those materials and to learn to teach from a problem-solving orientation. The Highland Park teachers on whom the project had the greatest impact were the ones who were paid during the summer to develop ideas and materials. Change might take place with minimal financial support but it will be less dramatic and take much longer than if adequately funded inservice had been available.

Summary

The School Component of the Preparing Elementary Teachers to Teach Mathematics (PETTM) project was a joint venture between the Mathematics Education Development Center at Indiana University (MEDC) and the faculty of Highland Park Elementary School. The project

supplied Highland Park with manipulative materials and a mathematics resource teacher who worked in classrooms with individual teachers. After-school workshops payed for with State funds were also provided. Highland Park teachers worked with project personnel to develop teaching techniques and write resource books on teaching from a problem-solving perspective. Preservice teachers (PSTs) from Indiana University worked with teachers at Highland Park on teaching mathematics to small groups of students.

The project was a learning experience for both Highland Park teachers and for project staff. The teachers who were most heavily involved in the inservice program and writing materials became outstanding models of how mathematics should be taught. These individuals continue to teach at Highland Park and also to provide inservice and mentoring to teachers in central Indiana. The project had varying impact on the other teachers at Highland Park. All have improved and many would be considered "top notch" mathematics instructors. PETTM staff have always known that teaching is a difficult job but the project has helped to keep them in touch with the trials and tribulations of teachers in the field. Finally, the PSTs at Indiana University benefit considerably from their interactions with the students and teachers at Highland Park.

PREPARING ELEMENTARY TEACHERS TO TEACH MATHEMATICS: A PROBLEM-SOLVING APPROACH

SCHOOL COMPONENT
PUBLICATIONS AND PRESENTATIONS

Publications Related to the School Component

Kloosterman, Peter (1992). Non-routine word problems: One part of a problem-solving program in the elementary school. *School Science and Mathematics*, *92*, 31-37.

[This article describes problem-solving instruction for fourth grade students at Dyer Elementary School. In addition to describing how problem solving was taught at Dyer, a number of "tips" are provided for others who would like to get students involved in solving non-routine problems.]

Kloosterman, Peter, & Cougan, Monica (in press). Students' beliefs about learning elementary school mathematics. *Elementary School Journal*.

[Based on interview data, this article describes some of the beliefs of Dyer elementary students with respect to problem solving. Trends by grade level and the relation between beliefs and achievement are also explored.]

Kloosterman, Peter, Gorman, Jacqueline, Kroll, Diana Lambdin, LeBlanc, John F., & Lester, Frank K. (1989). Mathematics for the 21st century: Preparing elementary teachers. Final report of a project sponsored by the Indiana Department of Education. *Resources in Education*, ERIC Clearinghouse on Teacher Education (ED 312 145).

[Final report of a 1988-89 series of six inservice workshops (organized by the IU MEDC and sponsored by the Indiana Department of Education) through which Dyer teachers from the NSF project were introduced to the NCTM Standards.]

Kroll, Diana Lambdin, Fry, Carol J., Gorman, Jacqueline, Kloosterman, Peter, LeBlanc, John F., Lester, Frank K., & Cassell, Sarah (1990). Implementing the NCTM Standards for School Mathematics for the 21st century. Unpublished final report of a project sponsored by

the Indiana Commission for Higher Education. *Resources in Education*, ERIC Clearinghouse on Teacher Education (ED 325 389).

[Final report of a 1989-90 series of six inservice workshops (organized by the IU MEDC and sponsored by the Indiana Commission for Higher Education) through which Dyer teachers from the NSF project were involved in activities related to implementing the NCTM Standards.]

Kroll, Diana Lambdin. (1989). Preparing elementary teachers to teach mathematics with a problem-solving approach: A university/school collaborative effort. *Resources in Education*, ERIC Clearinghouse on Teacher Education (ED 305 331).

[This paper describing the NSF project's university/school collaboration was originally presented at the March, 1989 annual meeting of the American Association of Colleges of Teacher Education, Anaheim, California -- see below.]

Kroll, Diana Lambdin, & Miller, Tammy. (in press). Insights from research on mathematical problem solving in the middle grades. In Douglas Owens (Ed.), *Research ideas for the classroom: Middle grades mathematics*. Reston, VA: NCTM.

[This chapter reviews the literature concerning research on mathematical problem solving and relates it to everyday concerns of middle school teachers. It was jointly authored by Lambdin Kroll, a member of the NSF project staff, and Miller, a teacher at Dyer Elementary who became interested in research on problem solving as a result of the NSF project.]

Presentations Related to the School Component

Gorman, Jacqueline, & Cougan, Monica (March, 1991). Monster, popcorn and Big Macs: An elementary math fair idea. *Regional Meeting of the National Council of Teachers of Mathematics*, South Bend, Indiana.

[This was a "how to" presentation which discussed the philosophy of doing a school math fair. The teachers were actively involved in the solution of some actual math fair problems. A packet of potential math fair problems was distributed and discussed, as was a schedule and collection of ideas on organizing a math fair.]

Kloosterman, Peter (October, 1990). Are story problems a curse of Western culture? A look at students' beliefs about mathematics. *Regional meeting of the National Council of Teachers of Mathematics*, Madison, Wisconsin.

[This presentation included a theoretical discussion of the relation between beliefs and achievement in mathematics together with examples from belief interviews with Dyer elementary students.]

Kloosterman, Peter, & Cougan, Monica (April, 1991). Students' beliefs about learning elementary school mathematics. *Paper presented at the Annual Meeting of the American Educational Research Association*, Chicago, Illinois.

[The presentation was similar to the article, by the same title, cited above.]

Kloosterman, Peter, Gorman, Jacqueline, & Cougan, Monica (October, 1991). Connecting the classroom with the field in elementary teacher education. *Regional Meeting of the National Council of Teachers of Mathematics,* Louisville, Kentucky.

[This presentation discussed the components at Indiana University (M118, T104, M201, E343) that make up the preservice elementary teacher's mathematics preparation and connected this to the experience at Highland Park Elementary School.]

Kloosterman, Peter, Kroll, Diana Lambdin, & Cougan, Monica (October, 1991). The Indiana University model for preservice elementary mathematics teachers. *Annual Meeting of the Indiana Council of Teachers of Mathematics,* Indianapolis, Indiana.

[This presentation described each of the courses that make up the Indiana University mathematics component for elementary teachers (M118, T104, M201, E343). Connections were made between the courses and the effect of T104 on the methods and field experiences was described.]

Kloosterman, Peter, & Stage, Frances K. (March, 1989). Measuring beliefs about mathematical problem solving. *Paper presented at the Annual Meeting of the American Educational Research Association*, San Francisco, California.

[This presentation was similar to the article, by the same title, cited above.]

Kroll, Diana Lambdin (March, 1989). Preparing elementary teachers to teach mathematics with a problem-solving approach: A university/school collaborative effort. *Annual Meeting of the American Association of Colleges of Teacher Education*, Anaheim, California.

[This paper described the NSF project's university/school collaboration. It was later accepted for distribution through the ERIC document system -- see above.]

Miller, Tammy, Bays, Lisa, & Merrifield, Mamie (October, 1990). Bridges + Time = Seeds. *Annual meeting of the Indiana Council of Teachers of Mathematics*, Indianapolis, Indiana.

[This presentation by three of the Dyer School teachers introduced elementary teachers to the notion of mathematical project problems and gave an overview of how such problems may be managed in the classroom.]

Pritchett, Margaret, & Cougan, Monica (October, 1989). Monsters, popcorn and Big Macs: An elementary math fair idea. *Annual Meeting of the Indiana Council of Teachers of Mathematics*, Indianapolis, Indiana.

[This was a "how to" presentation which discussed the philosophy of doing a school math fair. The teachers were actively involved in the solution of some actual math fair problems. A packet of potential math fair problems was distributed and discussed, as was a schedule and collection of ideas on organizing a math fair.]

Pritchett, Margaret, & Cougan, Monica (November, 1989). Monsters, popcorn and Big Macs: An elementary math fair idea. *Inservice meeting at Saint Richards Elementary School*, Indianapolis, Indiana.

[This was a "how to" presentation which discussed the philosophy of doing a school math fair. The teachers were actively involved in the solution of some actual math fair problems. A packet of potential math fair problems was distributed and discussed, as was a schedule and collection of ideas on organizing a math fair.]

PREPARING ELEMENTARY TEACHERS TO TEACH MATHEMATICS: A PROBLEM-SOLVING APPROACH SCHOOL COMPONENT

Description of Products Related to the School Component

Problem Solving Books for Classroom Use

Note: The books below are available in hard copy (for the cost of photocopying and optional hole punching or binding plus $2 plus postage) by contacting any *Kinkos* copy center in the nation and telling them that the books are on file in the Bloomington, Indiana *Kinkos*, 113 N. Dunn St., 812 339-3773. *Kinkos* is a nation-wide photocopy chain usually listed in the yellow pages of the phone book under "printers."

A Problem a Day for Primary People (approx. 364 pages) is a book of translation and process problems which can supplement any primary level elementary text book. The book consists of three sections: 150 problems for first grade, 150 problems for second, and 150 problems for third grade. Besides the problems, the book also discusses specific questions often asked by teachers such as "Why should I teach problem solving?" "What is my role as a teacher?" and "How do I evaluate problem solving?" Each section contains sample teaching questions, lessons wrap-ups, and problem variations. The problems in this book encourage students to use a variety of solution strategies and help them develo understanding of mathematics concepts.

A Logical Mystery Tour (approx. 166 pages) is a book of logic problems for students in grades 1 through 6. The book presents three types of logic problems: "Who am I" (48 logical elimination problems), "Line-Up" (36 sequencing problems), and "Matrix" (30 logical elimination problems suitable for solution by drawing a matrix). The problems within each section are organized from the least to the most difficult, and include teachers' pages with ideas for facilitating classroom discussion and guiding students through the problems. The introduction to this book also addresses common concerns of teachers and suggestions for evaluating student learning.

Projects for Real-World Problem Solvers (approx. 40 pages) is a collection of mathematical project problems which can supplement a regular mathematics program in grades 1 through 6. Each of the 14 projects is a "real-life" problem which is open-ended to allow the students to decide on the direction they should take and the strategies that should be used to solve the problem. These projects are usually assigned to be worked by groups of students over a period

of time. The book contains introductory materials on teaching actions, grouping students, and helping students who are having difficulty.

A Packet of Problems to Ponder (approx. 138 pages) is a book of 66 process problems for the intermediate grades. The first fifteen problems are presented with a teacher page which gives suggestions for possible strategies, discussions questions, hints, and variations of a problem. To aid in instruction, much of the book is organized by the most common strategy used to solve the problems. The final problems are provided for additional work and are organized by difficulty rather than solution strategy.

Videotapes

Title: *Teaching Fractions Using Cuisinaire Rods*
Code #: E1
Topic: Teaching Fractions with Cuisenaire Rods
Grade: 6
Teacher: Jacqueline Gorman

Title: *Teaching Problem Solving: The Making Flowers and Making Sandwiches Problems*
Code #: E2
Topic: Process Problems
Grade: 1 and 2
Teacher: Bette Calkins and Lisa Bays

Title: *Teaching Fractions Using Pattern Blocks.*
Code #: E3
Topic: Teaching Fractions with Manipulatives
Grade: 3
Teacher: Barb Burnett

Title: *Problem Solving Using Number Tiles*
Code #: E4
Topic: Problem Solving with Manipulatives
Grade: 4
Teacher: Margie Simmerman

Title: *Using Patterns to Find the Number of Squares*
Code #: E5
Topic: Process Problems
Grade: 4
Teacher: Jacqueline Gorman

Title: *A Geometric Investigation: How Many Lines are Determined by "X" Points*
Code #: E6
Topic: Teaching Geometry Using a Problem-Solving Approach
Grade: 6
Teacher: Jacqueline Gorman

Title: *Preparing Elementary Teachers to Teach Mathematics: A Problem-Solving Approach*
Code #: P1
Topic: Overview of PETTM project
Grade: Teacher Education
Teacher: Varies

Title: *Building Toothpick Bridges*
Code #: P2
Topic: Project Problems
Grade 6
Teacher: Tammy Miller

Title: *The Dyer Mathematics Fair*
Code #: P3
Topic: Project Problems
Grade: Varies
Teacher: Various PSTs

Title: *Teaching Problem Solving: The Tables Problem*
Topic: Process Problems
Grade: 3
Teacher: Jacqueline Gorman

Title: *Teaching Problem Solving: The Squirrel in the Tree Problem*
Topic: Process Problems
Grade: 3
Teacher: Jacqueline Gorman

Title: *Teaching Fractions Using Fraction Strips*
Topic: Teaching Fractions with Manipulatives
Grade: 5
Teacher: Mamie Merrifield

Appendix A: Highland Park Faculty

	1988-89	1989-90	1990-91	1991-1992
1st	B. Calkins J. Acton A. McNair	B. Calkins J. Acton M. Owens	B. Calkins J. Acton B. Kenner	B. Calkins A. Clark L. Wazicauski
2nd	K. Lentz M. Owens S. Anderson	K. Lentz L. Bays J. Stumpner	K. Lentz M. Owens J. Stumpner	K. Lentz M. Owens M. Austin
3rd	B. Burnett R. Crockett L. Bays	B. Burnett M. Austin P. Dowling	B. Burnett M. Austin E. Costlow	R. Crockett H. Sudbury
4th	H. Sudbury J. Stumpner	H. Sudbury T. Mobley	H. Sudbury T. Mobley M. Simmerman	T. Mobley J. Stumpner
5th	M. Merrifield P. Dowling	M. Merrifield M. Sturbaum	M. Merrifield R. Alexander	M. Merrifield M. Simmerman
6th	T. Miller P. Dowling	T. Miller R. Crockett	J. Gutierrez R. Crockett	B. Burnett R. Alexander

Item Description	Item Category	Quantity	Subject
100 ACTIVITIES FOR 100 BOARD	Book	1	Manipulative
A COLLECTION OF MATH LESSONS FROM GRADES 3 - 6	Book	1	Lessons
A COLLECTION OF MATH LESSONS FROM GRDS 1-3	Book	1	Lessons
A DOZEN DIZZY DINOSAURS	book	1	content
A MATTER OF FACTS-ADD-5WKBK	Book	3	Basic Skills
A MATTER OF FACTS-DIV-5WKBK	Book	7	Basic Skills
A MATTER OF FACTS-DIV-T	Book	1	Basic Skills
A MATTER OF FACTS-MULT-5WKBK	Book	6	Basic Skills
A MATTER OF FACTS-SUB-5WKBK	Book	4	Basic Skills
A MATTER OF FACTS-SUB-T	Book	2	Basic Skills
A NEW TWIST	Book	1	P.S.
ADDTRON	book	1	content
ADVENTURES WITH LOGIC	Book	1	Critical thinking
AFTERMATH(4C)	Book	4	P.S.
ATTRIBUTE BLOCK ACTIVITIES	Book	1	Manipulative
BIRDS, BIRDS EVERYWHERE	book	1	content
BOOK OF THINK, THE	book	1	P.S.
BRAINSTORMING ; ACTIVITIES FOR CREATIVE THINKING	Book	1	Critical thinking
BUILDING FOUNDATIONS IN MATHEAMTICS:A LABORATC	Book	1	Resource book
BUILDING THINKING SKILLS:	Book	4	Critical thinking
BULLETIN BOARD IDEAS FOR ELEMENTARY AND MIDDLEI	Book	1	Resource book
CHALLENGE BOXES: 50 PROJECTSIN CREATIVE THINKIN(	Book	1	Critical thinking
CHALLENGE MAGAZINE	Book	1	P.S.
CHANGING SCHOOL MATHEMATICS	Book	1	Resource book
COMPUTATIONAL ESTIMATION	book	1	estimation
CREATIVE CONSTRUCTIONS	book	1	geometry
Developing Estimation Book A	book	1	estimation
DEVELOPING MATH THINKING:FRACTIONS	book	1	critical thinking
DEVELOPING SKILLS WITH TABLES AND GRAPHS	book	1	statistics
DISCOVERING LOGIC	book	1	critical thinking
EL MATH:WHAT PARENTS .. ESTIMATION	book	1	resource book
EL. MATH WHAT PARENTS ...P.S.	book	1	resource book
ESTIMATION YEARBOOK	book	1	estimation
EVEN STEVEN	book	1	content
EVERY MINUTE COUNTS	book	1	resource book
EXPLORING W/PATTERN BLOCKS	book	1	
FACT-FINDERS	book	1	critical thinking
FISH FOR SUPPER	book	1	content
FRACTION FACTORY BOOKS	book	3	manipulatives
FROG ON A LOG	book	1	content
GAMES & ACT. W/BASE 10 BLOCKS	book	2	
GEOMETRY FOR GRADES K-6/NCTM	book	1	geometry
GEOMETRY YEARBOOK	book	1	geometry
GOATS IN BOATS	book	1	content
GOODTIME MATH EVENT BOOK	Book	1	lessons

Item Description	Item Category	Quantity	Subject
HOW TO CHOOSE AND CREATE GOOD PROBLEMS FOR PR	book	1	resource book
HOW TO DEVELOP P.S.USING THE CALCULATOR	Book	1	resource book
HOW TO ENCOURAGE GIRLS IN MATH AND SCIENCE	book	1	resource
HOW TO ENRICH GEO. USING STRING DESIGNS	book	1	geometry
HOW TO EVALUATE YOUR MATH PROGRAM	book	1	resource
HOW TO TEACH M. USING A CALCULATOR	book	1	resource
HOW TO TEACH PERIMETER, AREA AND VOLUME	book	1	measurement
HURRY HURRY	book	1	content
I HATE MATH BOOK(THE)	BOOK	1	P.S.
IDEAS FROM AT, 1-4	book	1	lessons
IDEAS FROM AT, 6-8	book	1	lessons
IT'S THOUGHT THAT COUNTS	book	1	
KIDS ARE CONSUMERS TOO	book	1	P.S.
LANE CO. GR 5	book	1	lessons
LANE CO. GR 6	book	1	lessons
LANE COUNTY GR 4	book	1	lessons
LANE. CO. INSERVICE GUIDE	book	1	lessons
LANE.CO . PROB. SOLVING	book	1	P.S.
LET'S PATTERN BLOCK IT	book	1	manipulative
LINE DESIGNS	book	1	geometry
LOGIC, ANYONE	book	1	critical thinking
LOOK INTO THE FACTS/+-5 WK	book	1	basic facts
LOOK INTO THE FACTS/+-T	book	1	basic facts
LOOK INTO THE FACTS/X+ 5 wk	book	10	basic facts
LOOK INTO THE FACTS/X+ T	book	2	basic facts
MAKE IT SIMPLER	book	1	P.S.
MASTERMIND:EXERCISES IN CRITICAL THINKING	book	1	critical thinking
MATH A WAY OF THINKING	book	1	lessons
MATH FOR GIRLS AND OTHER PROBLEM SOLVERS	book	1	P.S.
MATH ON THE WALL:	book	1	P.S.
MATH THEIR WAY	book	1	lessons
MATHEMATICS AND HUMOR	book	1	resource
MATHEMATICS INSTRUCTION IN THE ELEMENTARY GRAI	book	1	resource
MINDGLOW: CLASSROOM ENCOUNTERS WITH CREATIVE	book	1	critical thinking
MIRROR MIRROR	book	1	content
MR. MCMUNCH	book	1	content
OUR SISTER'S SURPRISE	book	1	content
PAINT A RAINBOW	book	1	content
PATTERN ANIMALS BOOK	book	1	
PATTERN BLOCK ACT. B	book	1	manipulative
PATTERN BLOCK ACTIVITIES	book	1	manipulative
PATTERN BLOCKS FOR PRIMARY PEOPLE	book	1	manipulative
PATTERN FACTORY,THE	BOOK	1	P.S.
PENNY PENGUIN'S PARTY	book	1	content
PETER PIPER	book	1	content

Item Description	Item Category	Quantity	Subject
PRIMARY BUILDING THINKING SKILLS	book	1	P.S.
PRIMARY BUILDING...TEACHERS	book	1	resource
PROBLEM SOLVING TECHNIQUES HELPFUL IN MATHEMAT	book	1	resource
PROBLEM SOLVING TIPS FOR TEACHERS	book	1	resource
PROLIFIC THINKERS GUIDE	book	1	critical thinkers
PUT YOUR MOTHER ON THE CEILING	book	1	critical thinking
RAND MCNALLY MATHEMATICS ENCYCLOPEDIA	book	1	resource
RESEARCH WITHIN REACH	book	1	resource
ROTATION TASK CARDS FOR PATTERN BLOCKS	book	1	
SAD KING COLE	book	1	content
SHINY SHELLS	book	1	content
SHOES IN TWOS	book	1	content
SPACES	book	1	critical thinking
SYMMETRY W/PATTERN BLOCKS	book	1	
TANGRAM ABC KIT	book	1	manipulative
TANGRAMATH	book	1	manipulative
TAP AND RAP	book	1	content
TEACHER MADE AIDS FOR EL.SCH. MATH:READINGS FR	Book	1	resource
TEACHER MADE AIDS FOR EL.SCH. MATH:READINGS FR	book	1	resource
TEACHING MATHEMATICS TO YOUNG CHILDREN	book	1	resource
TEACHING STAT. YRBOOK	book	1	resource
TEN SILLY SHEEP	book	1	content
THE BEAR'S BERRIES	book	1	content
THE GREAT CARROT MYSTERY	book	1	content
THE LAZY SHEPHERD	book	1	content
THE MEAN MACHINE	book	1	content
THE NICE MICE	book	1	content
THE PIRATES' GOLD	book	1	content
THE PIXIE'S TOYSHOP	book	1	content
THE QUEEN OF HEARTS	book	1	content
THE RED SHED	book	1	content
THE WIZARD'S WAND	book	1	content
THINKER TASKS : (4-6)	book	2	critical thinking
THINKING VISUALLY	book	1	critical thinking
UNDERSTANDING OPERATIONS+-	book	2	basic facts
VISUAL PATTERNS IN PASCAL'S TRINAGLE	book	1	P.S.
WHAT EXPERT TEACHERS SAY ABOUT TEACHING MATH	book	1	resource
WHAT'S IN THE CUPBOARD	book	1	content
WOLLYGOGGLES	book	1	P.S.
ZANY ZOO	book	1	content
A STRANGE STEW	book	1	content
CRITICAL THINKING ACTIVITIES IN PATTERNS, IMAGERY	bookbook	1	critical thinking
FAMILY MATH	books	1	lessons
A YEAR OF MATHEMATICS	CALENDAR	1	P.S.
CL.VIEW CARDS-SHAPES	Cards	1	

Item Description	Item Category	Quantity	Subject
CL.VIEW CRDS-FRACTIONS	cards	1	
CL.VIEW NETWORKS	cards	1	
CLEARVIEW FOLDER	cards	1	
COLOR CUBE ACTIVITY CARDS	Cards	1	Manipulative
DISCOVER cards	cards	1	critical thinking
ESS TANGRAM CARDS SETI	cards	1	manipulative
JUDY CLOCKS	clocks	1	
ATTRIBUTE BLOCKS POCKET	M	13	
ATTRIBUTE BLOCKS-DESK	M	10	
ATTRIBUTE DOMINOES	M	1	
ATTRIBUTE HOOPS	M	10	
Attribute PLASTIC SHAPES	M	2	
ATTRIBUTE TEMPLATE	M	1	
Balance SCALE	M	1	
BASE TEN BLOCKS WOODEN	M	1	
BUCKET OF PLAY MONEY	M	1	
CIRCULAR FRACTION SETS	M	1	
CLOCK DIALS	M	1	
COLOR CUBES	M	1	
CUISENAIRE ROD TEMPLATE	M	1	
CUISENAIRE RODS	M	30	
DOMINOES	M	18	
FRACTION BARS	M	1	
FRACTION CIRCLES	M	1	
FRACTION FACTORY PIECES	M	10	
FRACTION TILES	M	1	
GEOBLOCKS	M	1	
GEOBOARDS	M	32	
GEOSTRIPS	M	1	
GRAPHING MAT	M	1	
JUDY CLOCK	M	1	
MIRA	M	18	
MIRRORS	M	16	
MULTILINKING CUBES	M	2	
PATTERN BLOCK TEMPLATE	M	1	
PATTERN BLOCKS	M	7	
PEG BOARDS	M	20	
PEGS	M	1	
PLASTIC METER RULE	M	1	
SPINNERS	M	24	
TANGRAM TEMPLATE	M	1	
TANGRAMS	M	18	
TESSELLATION TEMPLATE	M	1	
TWO COLOR COUNTERS	M	2	
UNIFIX CUBES	M	4	

Item Description	Item Category	Quantity	Subject
PENTOMINOES	M.	30	
O.H BASE TEN BLOCKS	OH	1	
O.H FRACTION BARS	OH	1	
O.H. ATTRIBUTE BLOCKS	OH	1	
O.H. COLORED SQUARES	OH	1	
O.H. COUNTERS	OH	1	
O.H. CUISENAIRE RODS	OH	1	
O.H. FRACTION CIRCLES	OH	1	
O.H. FRACTION STRIPS	OH	1	
O.H. GEOBOARD	OH	1	
O.H. NUMBER TILES	OH	1	
O.H. SOLAR CALCULATOR	OH	1	
O.H.PATTERN BLOCKS	OH	1	
O.H.TANGRAMS	OH	1	
PASCAL'S TRIANGLE POSTER	Poster	1	P.S.
EVERYTHING'S COMING UP FRACTIONS	workbook	1	
BASE TEN BLOCKS (large set)		1	
BLANK DICE		2	
COOPERATIVE P.S. - WITH NUMBER TILES		1	
COOPERATIVE P.S. WITH ATT. BLOCKS		1	
COOPERATIVE P.S. WITH TANGRAMS		1	
DICE (36 pair)		8	
EXPLORATIONS 1		1	
EXPLORATIONS 2		1	
FIND IT!		1	
FRACTION BARS CARD SET		1	
GEOBLOCK JOB CARDS SERIES		1	
HANDS ON ATTRIBUTE BLOCKS		1	
HANDS ON GEPBOARDS		1	
HANDS ON PATTERNBLOCKS		1	
HANDS ON PEGBOARDS		1	
Hands on Pentaminoes		1	
HANDS ON TANGRAMS		1	
MOVING ON WITH ATTRIBUTE BLOCKS		1	
MOVING ON WITH GEOBOARDS		1	
MOVING ON WITH PATTERN BLOCKS		1	
MOVING ON WITH TANGRAMS		1	
NUMBER TILES		4	
PATTERN BLOCKS FOR PRIMARY PEOPLE		1	
PROTRACTORS (SET OF 10)		10	
ST. PROB. W/PATT BL. SERIES		2	
THINKER GAMES		1	Log. Thkg.
TRY-A-TILE, SET A		1	
UNDERSTANDING PLACE VALUE */		1	
WORKMAT - PUDDLEDUCK LAKE		1	

Item Description	Item Category	Quantity	Subject
WORKMAT- BUSTLETOWN SQUARE 1		1	

Appendix C
Final Interviews with Highland Park Faculty

During the last two months in which the PETTM project was active at Highland Park Elementary School (April and May, 1991), almost all teachers who had been involved with the project for a year or more were interviewed about the project and its affect on them. Among other things, the teachers were interviewed about how their views of mathematics and teaching mathematics changed as a result of the project. The interviews were done by the mathematics resource teacher and by a mathematics education graduate student who had been working at the school. Even though the interviews were not considered "confidential" the teachers were quite open about their feelings about the project. Following is a list of the five major questions that comprised the interviews and summaries of the comments that the teachers made. Note that the format of the interviewers' summary comments varied depending on how completely each teacher responded to the interview questions.

Interview Questions

1. Have your thoughts about what it means to teach mathematics/problem solving changed through your involvement with the Project?
2. Has your teaching been influenced by participation in the Project?
3. (If "Yes" to #2) What factors were influential?
4. What (in the Project) do you suggest should/could have been done differently?
5. Are there any other thoughts related to the Project that you'd like to offer?

Teachers' Responses

Bette Calkins (first grade; participant in summer writing projects)

View of mathematics. Bette believes that her view of what mathematics is has changed. Prior to the project, mathematics was computation and exactness. Now, mathematics is a way of thinking. It is tied into the world around us, it is usable. Mathematics is precise but it is more than that, it is the understanding behind the precision.

Teaching of mathematics. Bette believes that her teaching of mathematics has been dramatically changed. Before the project, Bette taught mathematics as an isolated subject, even though she attempted to integrate her other subjects. During class, time was spent on teacher demonstration and student practice. The textbook was followed page by page, with emphasis on accuracy of computation. Grades were taken on every paper and based solely on correctness of answers.

After three years of the project Bette's teaching of mathematics is very different. She still has a specific mathematics period, but mathematics is also discussed throughout the day in conjunction with other subjects including language arts and social studies. Mathematics applications and the usefulness of mathematics are emphasized. Mathematics classes are a time to teach and discuss concepts. Although there is some seatwork, students are asked how they arrived at their answers, to justify their procedures and their answers, and are strongly encouraged to challenge their teacher's answers and procedures. The textbook is now used as one of many resources. Bette uses it as a guide, but does not feel tied to its sequences, its timing or the amount of practice given in it.

Emphasis in the class is now based on concepts. Bette believes that every child is not equally ready for every concept. Therefore, every child does not have to do the same thing at the same time. She simply expects each child to go as far with a concept as they can. Manipulatives are now used often, both in centers and in class work. Time is also spent on mental math and number sense. Problem solving is woven into the class, both in the use of process problems and in the use of a problem-solving approach to teaching. Children are evaluated on their understanding as well as their mastery. Homework is seen as practice, therefore, homework assessment is for communication, not for grades. Bette will encourage children who make a simple computational error to go back and look at their work again, or to tell her what's wrong. Math grades are based on children's attitudes, risk tasking, ability to stay on task, and computational precision. Problem solving is also evaluated and appears on the students' report cards.

Catalyst. Bette believes that changes in the way she teaches mathematics were brought about through several things. First, she was unhappy about how she had been teaching mathematics before and was eager for new ideas. She believed that having someone around to offer encouragement, to answer questions, to coach, and to model was essential. The inservice workshops provided by state grants generated

new ideas and gave validity to ideas and beliefs that she already had.

Having the opportunity to work in the summers to write "Problem of the Day" notebooks, was invaluable. It gave Bette and the others who worked on those notebooks time to look through resources, to brainstorm with peers, and to think of themselves as professionals. The opportunity to provide inservice to other teachers allowed the notebook writers to realize how much they actually did know, and forced them to put knowledge, insights, and beliefs into words. Finally, Bette is a reflective teacher. she is constantly asking herself and others "What did I do," and "What could be done differently."

Disappointments. Bette believed that it would have been beneficial for the other members of the project staff to spend more time in the classrooms and for teachers at Highland Park to spend more time in each others' classrooms. Such interaction would have led to more cross-grade articulation of the curriculum and to a better understanding of how problem solving could be taught to various types of students. Bette realizes that many teachers are busy and would not take advantage of opportunities to visit and interact with their peers unless they were compensated for their time. She does, however, hope that more sharing and visitation will take place in future years.

Jayma Acton (first grade)

Jayma clearly felt that the PETTM project helped to make her a better mathematics teacher. She noted that she now does a "problem of the day" each morning and that her students really enjoy it. Jayma said that it is fun to see children thinking more about mathematics and spending less time on drill. She teaches strategies to help her children memorize facts and stated that "We don't just do 'How many in all?' or 'How many are left?' story problems." In addition to these problems, her class does problems that most teachers feel only older students could do. She feels most of her students do just fine on these challenging problems.

With respect to teaching, Jayma noted that "We do more talking about the problems and the kids demonstrate more on the board than I." She said that they show how they work the problem and do it their way. She wishes that she did even more problem solving and had more resources for doing group activities in mathematics.

Factors that Jayma mentioned as important in her improvement as a mathematics teacher included the availability of manipulative materials, resource books (e.g., book on math facts, notebook teachers made); after-school workshops and watching the mathematics resource teacher work with her children. She would have liked more time to share teaching ideas. Finally, Jayma noted that having pre-service teachers (PSTs) come into her classroom both helped her thinking and provided stimulation for her students.

Marilyn Owens (second grade during first and third year of the project, first grade during second year)

Marilyn did not have as much to say about the project as some of the other teachers but she indicated that she now sees problem solving as an important part of her instruction. She also sees the importance of hands-on teaching. When working with a class she does more to make mathematics interesting. She felt the state funded after-school workshops were useful. Other important features of the project were the regular visits from the mathematics resource teacher and use of the "Problem of the Day" materials developed by other teachers in the summer writing workshops. Marilyn felt that the mathematics fair was a good idea and that it should be continued at least once a year.

Karen Lentz (second grade)

View of mathematics. Mrs. Lentz views mathematics differently than she did before the project began. She now includes problem solving, mental math, and patterning in her mathematics instruction and feels that she understands the value of using manipulatives when possible.

Teaching of mathematics. Karen felt that the project had changed her teaching somewhat. Karen stated that her teaching had changed specifically in the area of teaching strategies for memorizing addition and subtraction facts. For example, she now emphasizes doubles, doubles plus one, and counting backwards strategies for addition facts. Karen also spends more time on number awareness, place value, evens and odds, and patterning. She uses clocks and money as manipulatives and does touch on problem solving. Karen expressed disappointment that she had not been able to use more manipulatives but felt that it was impossible given the composition of her classes the past three years. Karen's classes have consisted

mostly of "at risk" students and students with behavior problems. She felt that her class, especially during the last year of the project, needed so much work on social skills, that there was little time for problem solving or work with manipulatives.

Catalyst and disappointments. Karen believes that the inservice workshops changed her attitudes and that working with the mathematics resource teacher helped to give her new ideas. Karen also expressed a disappointment that she had not been more heavily involved in the project although that was partly her fault, partly the fault of project personnel, and partly the fault of circumstances beyond the control of her or the project.

Janet Stumpner (fourth grade during first year, second grade after that, participant in first summer writing project)

Like all the other teachers, Janet stated that the project had affected her views of mathematics and the way that she taught. She noted that in her class, "We talk through problems a lot more thoroughly--we talk about the details and become more familiar with what they're about." "I think I now stress more **how** to get to the answer instead of the answer." "I think the kids enjoy it; it makes it more fun. It's a more interesting and enjoyable way to go about it." In addition, she noted that she has much more confidence in her skills as a teacher.

With respect to factors that affected her teaching most, Janet noted that the summer she spent working on the resource notebooks had considerable impact on her. It was a time to read and reflect on better ways of teaching mathematics. Although Janet felt the project did help her, she felt that more continuous support in the classroom would have helped even more. She suggested bi-weekly visits by the resource teacher just to talk about progress and to provide encouragement. In Janet's words, "It's hard to change old habits. Good intentions are great, but it's just so easy to fall back into those old patterns." Janet's final comments dealt with her appreciation of the materials that the project provided and the contacts she had made with individuals from Indiana University.

Barb Burnett (third grade; participant in summer writing projects)

View of mathematics. Barb also believes that her view of what mathematics is has changed. Like Bette Calkins, prior to the project, Barb saw mathematics as computation. Now, mathematics is a process of arriving at an answer instead of just the answer. The concepts behind the answers are more important than the

answer. For Barb as well as Bette, mathematics is something which is integrated throughout the curriculum rather than an isolated subject.

Teaching of mathematics. Barb's teaching of mathematics has changed. She relies on the textbook less and has confidence in her own ability to judge what is important and relevant. She emphasizes concepts much more than she did in the past, to the point of not giving "A's" to students who answer all test questions correctly but cannot explain concepts. Mathematics is emphasized across the curriculum. Mental math, estimation, and strategies for learning the basic facts are given importance. Manipulatives are used, both in class teaching and in centers. Class time is a time for class discussion, as opposed to teacher demonstration. Process problems are given and discussed daily.

Catalyst. Barb believed that several factors influenced her change. She believed that having a mathematics resource teacher to provide ideas and support was essential. The after-school inservice workshops provided with state funds also strongly influenced her.

Barb's final comments indicated that having the opportunity to participate in the summer writing sessions was invaluable. It gave her time to look through resources and to try to adapt those resources to what she felt was needed for students at Highland Park. The opportunity to provide inservice workshops for other teachers helped to build her confidence and forced her to analyze what she did so that she could describe her actions to other teachers. Finally, Barb, like Bette is a reflective teacher. She is constantly asking herself how she can improve.

Lisa Bays (second grade during first project year, third grade during second year, left Bloomington during final year, participant in summer writing projects)

View of mathematics. Lisa stated that she used to see mathematics as computation. Now, she believes that the heart of mathematics is really critical thinking and applications. She has become enthralled with logic, which she never associated with mathematics before. Lisa is attempting to integrate mathematics and problem solving into all areas of her curriculum, touching on it in every subject.

Teaching of math. Lisa was teaching in a fifth-grade classroom in a northern suburb of Indianapolis during the final year of the project. She stated that the move helped her realized how much she had grown from the project, and how

thoroughly she uses problem solving in both math and language arts.

Lisa was a first year teacher at the beginning of the project, so she could not say how her teaching of mathematics changed because of the project. She did speak, however, about how she taught mathematics in a new school, without the aid of the project staff. Her goal for the year was to have students use more critical thinking skills during mathematics rather than rely on rote memory skills. She felt that she was succeeding when her students started, without any guidance from her, to apply their math problem-solving strategies to help them analyze their stories in language arts. Lisa related the story of how her students were analyzing a detective story and one of them stated that it was solved by the detectives "acting out" the problem. From then on, her students tried to link up their math strategies with the problem solutions in their readers.

Lisa noted that her students put a lot of effort into writing their own problems as well as taking class problems and rewriting them, to make them harder or easier. She also mentioned that she uses manipulatives to help the students come to a fuller understanding of mathematical concepts.

Catalyst. Lisa cited the two most important project-related factors in her development at a mathematics teacher were the state sponsored after-school workshops and the summer writing sessions. Lisa felt that the workshops were extremely important in showing her how to use a wide variety of manipulatives. The summer time sessions were very helpful in several ways. They allowed her to explore which resources were available to her, letting her know what was out there, what she liked, and gave her time to decide how she wanted to develop certain topics. They also provided her with a resource which she and her students used everyday as a model to make up their own problems. Finally, the sessions allowed her to learn from other teachers and to feel part of a supportive, collegial network.

Lisa as a catalyst. Lisa was involved in teacher inservice while she was with MCCSC. Since leaving Bloomington, she has not been involved with formal inservice but has become the informal mathematics resource teacher of her building. She works with other teachers at her school to order manipulatives and resource books, and provides suggestions for using those materials.

Disappointments. Lisa's largest disappointment was leaving Highland Park before the last year of the project. Even though she influenced her current building teachers to buy manipulatives, she missed the access to the Highland Park mathematics laboratory. She also was disappointed that she missed the opportunity to become involved with more formal inservice. However, she feels that she is still going strong, even though she has been "on her own" for a year now.

Marilyn Austin (on leave during first year of project, third grade during second and third year)

Rather than changing her beliefs about the nature of mathematics, Marilyn noted that the project reinforced her notions that students need lots of hands-on activities to understand mathematics. She stated that her participation in the project has caused her to use more questioning in her teaching, to stress in-depth thinking more, and to encourage her students to use a variety of strategies to solve problems. The workshops she attended during the second year of the project together with her observations of the resource teacher working with her class had the greatest effect on her. She did note that she felt missing the first year of the project was a major handicap. In Marilyn's words, "When you're not one of the main spokes, you just don't get the same information out of it." She wished the principal had been more open to volunteers for the teachers' advisory committee for the project, noting that because she was not chosen as a leader, she did not get as much out of the project as she had hoped. "There were people who were interested who didn't even have a chance to really have any input as to who was chosen to do that." "It made an effect on what my initial dealings were towards the program." The only final comment that Marilyn had was that she wanted to reinforce how helpful, supportive, and effective the mathematics resource teacher was.

Ellen Costlow (third grade during third year of the project, her first year of teaching)

Ellen was somewhat unique in that prior to participation in the project, her only experience at teaching mathematics had been student teaching and participation in the M201 field experience as an undergraduate. She had taken mathematics methods and content courses from project staff and thus, rather than

seeing new ideas about how to teach mathematics, she was more in a position of trying to implement ideas she had been exposed to as a student. She was using manipulatives, encouraging her students to figure out problems several different ways, and using what she called "thinker problems" where students had to develop their own solution strategies. She continually asked students "Are we there, did we find what we were looking for?"

Although the third year of the project was Ellen's first full year of teaching, she noted that she changed during the course of the year. By the end, she was relying less on the textbook and worksheets and more on manipulatives and the resource books developed in the summer writing workshops. She was doing more "problems of the day," more problem solving, and more "process problems". She was also more tolerant of noise and the loose classroom structure often necessary for good student interaction.

When asked about the PETTM project specifically, Ellen noted the importance of modeling and support by the mathematics resource teacher and other Highland Park faculty. "If I wouldn't have had that modeling, I wouldn't have been able to come out into the classroom, because you go back to what you know. But I didn't have to go back, really, to elementary times. I just went back to sitting in the college class, going back to what I knew." "That's easy [games played in class], but the only way you're going to know how to teach it is to actually do it on your own and we were provided with that opportunity."

Ellen would like to see the PETTM project and philosophy exported to other schools. She also noted that a number of her students had been in Lisa Bays' class in second grade and that these students started third grade with a good grasp of how to solve mathematics problems. "They still are my leaders in the class in problem solving, and they don't always do the best in basic facts but they *are* heads and shoulders above some of the others in basic facts, though they're not absolutely perfect. But as far as problem solving goes, they aren't worried to take risks, they're very open to trying to figure out problems, they're willing to sit and think about it. They've already learned it." Ellen noted that she can't wait to get students who

have been taught through a problem-solving approach since first grade. "It'll be easier if it's kept up, if all teachers start in like this, to do it over and over again. And it will be, not really easier to teach, but we can go ahead and move on."

Tom Mobley (fourth grade)

Tom's comments during the interview were fairly brief but he indicated that the project had affected him and the way that he taught. He stated that he incorporated new ideas including problem solving into the way he previously taught, and felt he was making mathematics more interesting in the process. The resource notebooks provided him with ideas for teaching topics from a different perspective. During the second year of the project, one project staff member spent about a dozen mathematics periods working with his students. Another half dozen periods were spent by the mathematics resource teacher during the third year of the project. Tom was very pleased with the activities these individuals presented but wished they could have done more. He noted that his students both enjoyed and benefited from this interaction with other adults.

Harvey Sudbury (fourth grade)

When asked if the PETTM project had changed his view of mathematics, Harvey noted that to some extent it had. "We've tried to relate it [mathematics] to real world situations more than just sort of abstract things and rote-type learning without putting it in a context where you can relate it to the real world." He said that he was "getting kids to really think about what they're doing and think it through, why they're doing what they're doing and make it more enjoyable than just sort of a boring-type exercise." Harvey now does more group work in problem solving, tries to provide more interesting problems; uses a problem solving approach and gets students to think more, especially through story problems. He also feels that part of his job is to get students to enjoy and appreciate mathematics, as well as to see its usefulness.

The features of the project that Harvey felt affected him most were the after-school workshops, watching the mathematics resource teacher and the other PETTM staff member work with his students, and having an opportunity to use

some of the activities in the resource notebook. Overall, he was quite happy with the project although he noted that he would like to have contact with PSTs more than once a week and work with them to coordinate their lessons with the mathematics he is teaching.

Mamie Merrifield (fifth grade; participant in summer writing projects)

View of mathematics. During the past three years, Mrs. Merrifield has come to believe that mathematics is more than what is presented in the text book. It is no longer a subject that can be taught with just paper and pencil, it is a subject that needs to be talked about, written about, and understood through the manipulation of objects. Mamie said that she is intrigued by challenging mathematics problems. She used to be bothered by not knowing that much about how to solve unusual problems but now she is confident that she can both solve "real" problems and teach her students to be good problem solvers.

Teaching of mathematics. Mamie was typical of the other Highland Park/Dyer teachers before the project began in that her sole mathematics resource was the textbook. Mamie now believes that talking about mathematics is essential for both herself and her students. Thus, she uses her textbook as a focus when planning her lessons, but rounds out her plans with classroom discussion and the use of concrete materials. She strongly relies on materials from the mathematics lab to help give her innovative ideas. She also attempts to use process problems that fit with the subject matter she is teaching.

Catalyst. Mamie identified two factors which she felt were critical to her improvement as a mathematics teacher. These factors were time for experimenting and reflection, and support of other professionals. Mamie felt that teachers need time to understand the philosophy behind new ideas and to figure a way to integrate this philosophy into the reality of their classrooms. They also need time to implement their new skills while support is close by. Mamie believes that she would not have grown as much if this project had been any shorter. Besides time, Mamie believes that the support she received from IU was essential. The support, which came in the form of modeling teaching techniques, advice, and the giving of

feedback, was as crucial as the time. Mamie felt that her time spent writing and revising the resource books was also crucial to her growth.

Mamie said that prior to the beginning of the project, she was unaware that there were new or different approaches to teaching mathematics. She felt that becoming familiar with the literature, especially the NCTM *Standards*, helped her to see better ways to teach. Mamie also stated that the MEDC staff was open and willing to share, and that she appreciated their collegial attitude.

Disappointments. Mamie's main disappointment about the project was the fact that some of the faculty who had worked with the project, left Highland Park. Even though Mamie views herself as having knowledge to pass on to new faculty, she doesn't have adequate time to devote to them and she believes that many of them do not have the interest in mathematics that their predecessors had. She also is disappointed by the length of the project, expressing a wish that there were at least two more years of support.

Rosalee Crocket (third grade in first year of project, sixth grade in last two years)

View of mathematics. Rosalee said that she is no longer afraid of mathematics. Over the three years of the project, she has come to view it as a subject which is logical and where answers can be figured out by playing with numbers. In fact, Rosalee has discovered that she is good at both problem solving and mathematics, and has come to enjoy teaching them.

Teaching of mathematics. Rosalee believes that both the pedagogy and the content have changed in her mathematics classes. Mathematics is taught through discussion and through the use of questions. Rosalee has found that by having students discuss mathematical ideas, she can find out more about both their knowledge and misconceptions. Her mathematics content now includes geometry, estimation, mental math, and problem solving. Rosalee stated that she now emphasizes common sense, expecting her students to know if an answer is reasonable or not.

Catalyst and disappointments. Rosalee's primary catalyst was the model teaching provided by the mathematics resource teacher. She felt that this gave her a chance to see other values and different teaching techniques. She also appreciated the support given by the resource teacher with curriculum planning. Rosalee could not think of any features of the project that were disappointing to her.

Tammy Miller (sixth grade in first two years, went to another school during third year; participant in summer writing projects)

View of mathematics. Before the project, Tammy claimed that she was terrified of teaching mathematics. Self confidence has grown in her ability to teach math and this is mostly because she views mathematics differently. She now trusts that when she and her students are presented with a problem, they will be able to arrive at a solution. She said that she often presents a problem to her students by saying, "We're going to [attempt this problem]. I don't know how, but we'll figure it out." This is problem solving in it's truest sense. She allows the students to take over. This gives them confidence, as well as ownership of their work, both of which build motivation.

Teaching of math. In the past, Tammy allowed the textbook to drive her teaching of mathematics. She included no problem solving, no applications and no real-world learning. In fact, she stated that no learning beyond computation occurred.

Now, Tammy's students needs and interests drive her curriculum. Every unit includes real world applications as well as problem solving. For example, on a unit about area and perimeter, her students designed a city, each student made a blue print of a building in the city which included fire stations, stores, schools. The students then built the city including the streets from file folders. The students took leadership in this project. Tammy allowed them to push her, beyond the limit of where she thought they could go. The students solved the problems as they arose because Tammy did not have the answers.

Catalyst. Tammy felt that no single thing caused her to change the way she taught mathematics. It was the total package, including the math resource teacher, the inservice workshops, and the summer writing projects. She felt the support provided by the resource teacher was the single most important element. Knowing that there was someone to fall back on allowed her to take risks. She emphasized how important it was that the resource teacher was someone who teachers trusted enough to make mistakes in front of. Tammy also emphasized how important the summer writing project was to her development. She believes that the process of

writing, looking through materials, and evaluating ideas allowed her to see mathematics differently and gave her confidence in herself as a professional.

Tammy as a catalyst. Tammy has been heavily involved in providing inservice for other teachers in the school corporation. She has provided inservice in mathematics and other fields, such as TESA (an effective teaching program), and Write-More-Learn-More (a writing program). She has tried to act as a mathematics resource teacher at her present site, and is currently involved in a project with other intermediate-grade teachers to integrate all subjects around a topic. Tammy also talked the principal in her current school into investing $4,000 in a mathematics laboratory.

Disappointments. Tammy's major disappointment was the same as that voiced by many, the project was not long enough. She was "alone" during the year in her new school and realized how much she had grown. Tammy feels that she has the self-confidence to continue to grow, but wonders how much better she would have been with another year of support. She would have liked more coaching in how to act as a resource teacher, and also more information about teaching mathematics to primary-grade students.